Point Sources in the Cosmic Microwave Background?

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ABSTRACT

Non-Gaussian imprints on the cosmic microwave background radiation (CBR) sky are within the grasp of current experiments. A clear non-Gaussian signature would be point-like sources. We have examined the nature of possible point sources that were tentatively identified in a recent high frequency CBR experiment with half-degree resolution (Cheng et al. 1994: MSAM). The effects of local foreground sources, including cold dust clouds, radio sources and the Sunyaev-Zeldovich effect due to foreground rich clusters are considered, and the effective spectral slopes of these various foreground contaminations are calculated. Radio source emission and the Sunyaev-Zeldovich effect are ruled out as the explanation of the possible MSAM sources. Modeles are examined of extremely cold dust clouds which are located in the solar neighborhood, the interstellar medium, the galactic halo or at cosmological distances. We estimate the cloud mass and dust grain parameters, and in particular the grain size distribution, that are required in order to produce a detectable signal in an MSAM-type experiment. It is shown that cold dust clouds can have an important effect on CBR experiments only if the clouds are nearby, and located within a disc scale height of the solar neighborhood. Cold dust emission remains a possible source of far-infrared signal at the level of the detected CBR fluctuations on degree scales, but may be ruled out if the dust emissivity index satisfies $\alpha = 1.5 \pm 0.5$.

1 Introduction

Valuable information about the early universe and the physical processes that generate the primordial fluctuations from which cosmic structure formed can be gained from measurements of cosmic microwave background radiation (CBR) temperature anisotropies (White, Scott & Silk 1993). An especially important issue is the Gaussian nature of the temperature anisotropies. Gaussianity in the linear regime is a generic consweqeunce of most inflationary theories for the origin of the fluctuations. However none of these models fare particularly well at accounting for the large-scale power spectrum of density fluctuations on all observed scales, and rather extreme solutions have been advocated (e.g. Peacock and Dodds 1994; Peebles 1994; Bartlett, Blanchard, Turner and Silk 1994). Hence deviations from Gaussianity are a possibility that can only be limited by experiment. Although significant progress has been made in the understanding of the CBR since the detection of fluctuations at 7° angular scale by the COBE satellite (Bennett et al. 1992; Smoot et al. 1992; Wright et al. 1992), the Gaussianity question remain unresolved. Despite the full-sky coverage achieved by COBE, the combination of beam smoothing and the effects of cosmic variance (Luo 1994; Hinshaw et al. 1994) preclude COBE alone from testing Gaussianity. At the same time, while the detection of degree-scale fluctuations intrinsic to the CBR is a remarkable achievement, the datasets at these intermediate angular scales are still too small to carry out Gaussianity tests, although tests at these angular scales would certainly be decisive once large sky coverage is achieved (Coulson et al. 1994).

Despite all these difficulties, there are non-Gaussian imprints on the CBR sky that are within the grasp of current on-going experiments. A clear non-Gaussian signature would be the detection of point-like sources. In fact, two candidates for such sources may have been detected by the medium scale anisotropy measurement (MSAM) experiment. There are serious issues of data analysis that pertain to whether or not possible point sources are subtracted before attempting to measure temperature fluctuations: we do not address such issues here. Rather, we ask the question: could possible foreground sources produce point source-like signals in a CBR experiment at MSAM resolution and frequency?

Various topological defects, notably soft-domain wall bubbles (Goetz & Nötzold 1991; Turner et al. 1991), the global monopoles (Bennett & Rhie 1991) or texture (Turok & Spergel 1991) are capable of producing spotlike CBR anisotropies of any desired size by choosing appropriate model parameters. However, before relying on topological defects as the interpretation of candidate sources, one has to carefully filter out any foregrounds. In carrying out the experiments, CBR anisotropy signals have to be separated carefully from local foreground sub-millimeter and millimeter radiation fields. Three possible foreground sources are studied in this paper. These are cold dust clouds, nonthermal extragalactic radio sources and the Sunyaev-Zeldovich effect in foreground galaxy clusters. Multifrequency

measurements have previously been studied as a ttechnique for removing the foreground (Brandt et al. 1994), with a focus on the point-like sources listed above.

The arrangement of this paper is as follows: an effective spectral index for point sources is introduced in section 2, and results for radio sources, dust clouds and the SZ effect are presented and discussed in section 3. We conclude that both radio sources and the SZ effect are ruled out as a possible explanation of MSAM-type sources, that is to say, several *sigma* fluctuations that are point-like at ~ 30 arc-min resolution and have a spectral energy distribution that, crudely at least, is indistinguishable from that of the CBR. Cold dust emission remains a possibility, but we find that this option also may be ruled out if a conventional value for the dust emissivity $\alpha = 1.5 \pm 0.5$ is adopted.

2 Effective Spectral Slope of Point Foreground Sources

A multi-frequency technique has been used in most CBR experiments for the purpose of removing foreground emission. The spectral information in each pixel of the observations is used as a discriminator between foreground and the true CBR signal. In the MSAM experiment on which we focus in this paper, four frequency channels have been used, $\nu = 5.6, 9.0, 16.5$ and 22.5cm^{-1}. By fitting a model for cold dust emission to these four frequencies, we can study the spectral features of the emission, and the range of parameters which can still give rise to a spectrum that is close to that of the cosmic microwave background radiation.

Let us first define the effective spectral slope of cold dust emission. Given the spectrum of dust emission, S_ν, the effective power-spectral slope α_{eff} is

$$S_\nu = (\frac{\nu}{\nu_0})^{\alpha_{eff}} I_B(\nu, T_0), \quad I_B(\nu, T_0) = B_\nu(T_0)\frac{xe^x}{e^x - 1}\left(\frac{\delta T}{T_0}\right)_{\rm rms}, \tag{1}$$

where ν_0 is a reference frequency, which we choose it to be $\nu_0 = 5.6\text{cm}^{-1}$, $B_\nu(T_0)$ is the blackbody radiation spectra, $T_0 = 2.726K$ is the CBR temperature and $x = h\nu/KT_0 = 2.97\frac{\nu}{\nu_0}$. At half-degree scales, the expected temperature anisotropy is $\left(\frac{\delta T}{T_0}\right)_{\rm rms} \sim 1.0 \times 10^{-5}$. Thus, the expected CBR flux $I_B(\nu, T_0)$ is

$$I_B(\nu, T_0) = 6.5 \times 10^5 (\frac{\nu}{\nu_0})^4 e^{2.97\nu/\nu_0}(e^{2.97\nu/\nu_0} - 1)^{-2}\text{JySr}^{-1}. \tag{2}$$

By this definition, the effective spectral slope $\alpha_{eff} = 0$ for true CBR anisotropies.

One can determine the effective spectral slope from measuring the flux S_i at four different frequencies ν_i. Let $y_i = log[S_i/I_B(\nu_i, T_0)]$ and $x_i = log(\nu_i/\nu_0)$, the best fit spectral slope can be found through minimizing χ^2,

$$\chi^2 = \sum_i (y_i - A - Bx_i)^2/N, \quad N = 4, \tag{3}$$

here A, B are two constants and the best fit slope B is our effective spectral slope α_{eff}, which is found to be

$$\alpha_{eff} = \frac{\sum_i x_i y_i/N - (\sum_i x_i/N)(\sum_i y_i/N)}{\sum_i x_i^2/N - (\sum_i x_i/N)^2}. \tag{4}$$

We now discuss the flux S_ν. The flux in each pixel is sampled by a two-beam or three-beam chop. We will consider the situation where in one position there is a compact source of unknown origin. By a compact source, we mean that the angular size of the source is smaller than the beam width, which is $\theta_m = 0.425 \times 28' = 12'$. To simplify the problem, we consider a two-beam square-wave chop (in the MSAM experiment a sine-wave chop is used, and the position of the compact source matters if the angular size is much less than the beam width). In this case, the observed flux is

$$S_\nu = \pi\theta_m^2 I_B(\nu, T_0)\delta + j_\nu, \tag{5}$$

where

$$\delta = \left(\frac{\Delta T}{T_0}\right) / \left(\frac{\Delta T}{T_0}\right)_{rms} \tag{6}$$

is the normalized temperature anisotropy. It is a random Gaussian variable of zero mean and unit variance. The MSAM beam width is $\theta_m = 0.425 \times 28' = 12$ arcminutes, and thus the expected CBR flux at $\nu_0 = 5.6\text{cm}^{-1}$ is $I = 1.4Jy$.

We parametrize the observed flux from any pixel that contains a compact source by a parameter r,

$$S_\nu = \pi\theta_m^2 I_B(\nu, T_0)[\delta + rI(\nu/\nu_0)], \tag{7}$$

where r is the ratio of the contribution from the compact sources to CBR temperature anisotropies and $I(\nu/\nu_0)$ is the frequency dependence which is normalized so that $I(\nu) = 1$ at $\nu = \nu_0$.

As shown in Fig.1, three possible foreground sources are studied in this paper. These are cold dust clouds, nonthermal radio sources and the Sunyaev-Zeldovich effect in foreground galaxy clusters. For each case, the flux j_ν from each source is discussed in detail in the following.

2.1 Radio Sources

The flux is assumed to be

$$j(\nu) = A(\frac{\nu}{\nu_0})^B, \tag{8}$$

here $\nu_0 = 5.6\text{cm}^{-1}$ is the reference frequency and $B \approx -1$ is the spectral index of the radio emission from candidate sources.

For the radio sources as modeled above,

$$r = \left(\frac{\theta_d}{\theta_m}\right)^2 \frac{A}{1.5Jy}, \quad I(\nu/\nu_0) = 0.057(\frac{\nu}{\nu_0})^{B-4} e^{-2.97\frac{\nu}{\nu_0}} (e^{2.97\frac{\nu}{\nu_0}-1})^2. \tag{9}$$

Here θ_d is the angular size of the radio source.

2.2 The Sunyaev-Zeldovich Effect

The typical angular scale of a foreground rich cluster is of order several arcminutes, which lies in the range of the MSAM sources. The scattering of microwave photons by hot electrons in the intracluster gas will make a rich cluster a powerful source of submillimeter radiation. The flux density is given by (Sunyaev & Zeldovich 1980)

$$j_\nu = y\left[x\frac{e^x+1}{e^x-1} - 4\right]\frac{xe^x}{(e^x-1)} B_\nu(T_0), \tag{10}$$

where $x = h\nu/kT_0$ and $y = \int (kT_e/m_ec^2)\sigma_T n_e dl$.

For the SZ effect, the ratio r and frequency dependence $I(\frac{\nu}{\nu_0})$ is

$$r = \left(\frac{\theta_d}{\theta_m}\right)^2 \frac{y}{(\delta T/T)_{rms}}, \quad I(\frac{\nu}{\nu_0}) = -1.41[\left(\frac{\nu}{\nu_0}\right)\frac{e^{\frac{2.97\nu}{\nu_0}}+1}{e^{\frac{2.97\nu}{\nu_0}}-1} - 4]. \tag{11}$$

2.3 Dust Emission

Let us consider a single dust cloud which is located a distance D away from our location. The flux from the dust cloud is (Greenberg 1968; Kwan & Xie 1992)

$$j_\nu = \frac{1}{4\pi D^2}\int\int n_d(r_d, T)B_\nu(T)\epsilon_v \pi 4\pi r_d^2 e^{-\tau_\nu} dr_d dT, \tag{12}$$

where $B_\nu(T) = 4.63\times10^9\nu^3(\exp\frac{4.8}{T}\nu - 1)^{-1}\mathrm{Jy}Sr^{-1}$ is the brightness function of a black-body with temperature T and ν is in units of 100 GHz. Here, $n_d(r_d, T)$ is the distribution of dust grains as a function of grain size r_d and grain temperature T, $\epsilon_\nu = \epsilon(\frac{\lambda}{2\pi r_d})^\alpha$ is the emissivity of the dust grains and τ_ν is the optical depth of the dust emission. Since reabsorption of the dust emission is expected to be negligible, the emission should be optically thin so that $\tau_\nu = 0$. When the cloud consists of dust paricles of a single radius, and therefore of a single temperature T_d, the flux from the dust cloud is:

$$j_\nu = \frac{N_d}{D^2}\pi r_d^2 \epsilon_\nu B_\nu(T_d), \tag{13}$$

here, N_d is the total number of dust particles in the cloud.

For dust emission, in addition to the parameter r which denotes the ratio of dust emission flux to the expected rms CBR flux, we have two additional parameters: the dust temperature T_d and the emissivity index α. r and $I(\frac{\nu}{\nu_0})$ are given by

$$r = (N_d/D^2)\pi r_d^2 \epsilon/(\pi\theta_m^2(\Delta T/T_0)_{rms}), \quad I(\frac{\nu}{\nu_0}) = \left(\frac{\nu}{\nu_0}\right)^{\alpha-1} \frac{\left(e^{2.97\nu/\nu_0} - 1\right)^2}{e^{2.97\nu/\nu_0}\left(e^{2.97\frac{\nu}{\nu_0}\frac{T_0}{T_d}} - 1\right)}. \tag{14}$$

3 Results and Discussions

At the four frequencies $\nu_i = 5.6, 9.0, 16.5, 22.5\text{cm}^{-1}, i = 1, ..., 4$, which are used in the MSAM experiment, the observed flux is parametrized as

$$S_{\nu_i} = \pi\theta_m^2 I_B(\nu_i, T_0)[\delta + rI(\nu_i/\nu_0)], i = 1, ..., 4. \tag{15}$$

The physical interpretation of r is straightforward: $r/(1+r)$ is the percentage of the total flux contributed by foreground sources at 5.6cm^{-1} To determine α_{eff} from Eq.(4), one has to take into account the fact that δ is a random variable. In our calculations, we generate 100 Monto-Carlo realizations of δ each time when computing α_{eff}, and the mean and variance of α_{eff} for the different foregrounds are shown in Fig. 2 (a-f).

3.1 The Sunyaev-Zeldovich Effect

In Fig. 2a, the effective spectral slope for the SZ effect is shown. Again, we find that at the 1σ level, r greater than 0.30 is ruled out based on spectral analysis. We conclude that no more than 23% of the signal comes from the SZ effect of a foreground rich cluster if the spectral slope lies within ± 0.3 of the CBR spectral index.

3.2 Radio Sources

In Fig. 2b, the effective spectral slope for $B = -1.0$ radio sources are shown for different ratios r. Again at the 1σ level, r greater than 0.40 is ruled out based on spectral analysis. We conclude that no more than 28% of the signal comes from radio emission if the spectral slope lies within ± 0.3 of the CBR spectral index.

3.3 Cold Dust Emission

Estimation of the dust emission is more complicated than the calculation of the radio source contribution and the SZ effect. We need to specify the dust temperature T_d, the dust emissivity α and the geometry of the dust grains. The dust geometry may be dominated by whiskers or fractals: we will address this point later. In Figs. 2c, 2d, 2e, 2f, the effective

spectral slopes for $T_d = 4K$ cold dust with dust emissivity $\alpha = 1.5, 1.0, 0.5, 0.0$ are shown. The spectral slope of dust emission can be close to that of the CBR if the dust emissivity is small ($\alpha = 0.5, 0.0$), as shown in Figs. 2e, 2f. Dust emission can be responsible for the putative MSAM point sources if the dust emissivity is small. However, if we adopt for the physical value of the dust emissivity $\alpha = 1.5 \pm 0.5$, then no more than 50% of the total flux can be due to cold dust.

How much dust can give rise to a flux that could cause problems for medium-scale CBR experiments? For the time being, let us assume that the MSAM 'sources' are due to foreground dust emission, and we will estimate the required dust mass. To determine the cloud mass, we choose the mass density of dust grains to be $\rho_d = 3g/cm^3$ (Hildebrand 1983). From Eqs. (13), the mass of the dust cloud is

$$M = \frac{4\pi}{3}\rho_d r_d^3 N_d = 8.58 \times 10^{28} (\frac{S_{obs}}{1Jy})(\frac{\theta_{FWHM}}{\theta})^2 (\frac{0.1}{\epsilon})(\frac{r_d}{1\mu m})^{1-\alpha}(\frac{D}{1pc})^2 \nu^{-3-\alpha}[e^{\frac{4.8}{T}\cdot\nu} - 1]\text{grams} \tag{16}$$

Two 'sources' are reported at $\nu = 5.6\text{cm}^{-1}$ by the MSAM experiment (Cheng et al. 1994). The flux from one source is 3.7 ± 0.9 Jy, the other is 2.9 ± 0.7 Jy. Both sources are unresolved at $\theta_{FWHM} = 28'$. Let us assume that the angular size of the dust cloud is $\theta_d = 14'$ in order to minimize the beam-smoothing effect and dust emissivity $\alpha \approx 1.5$. The estimated mass is

$$M_1 = (1.2 \pm 0.3) \times 10^{29} (\frac{r_d}{1\mu m})(\frac{D}{1pc})^2 \text{grams} \tag{17}$$

for the 3.7 ± 0.9 Jy source and

$$M_2 = (0.9 \pm 0.3) \times 10^{29} (\frac{r_d}{1\mu m})(\frac{D}{1pc})^2 \text{grams} \tag{18}$$

for the 2.9 ± 0.7 Jy source.

The dust clouds may be located in the solar neighborhood ($D < 100\,\text{pc}$), the interstellar medium ($100\,\text{pc} < D < 1\,\text{kpc}$), the dark halo ($5\,\text{kpc} < D < 50\,\text{kpc}$) or even be at cosmological distance ($D \sim 3000\,\text{Mpc}$). Let us look into all these possibility in detail.

3.3.1 Dust in the Solar Neighborhood

Here, the solar neighborhood is loosely defined as the region centered around the sun and within the disc scale height ($D < 100\,\text{pc}$). In the inner solar neighbourhood, $D < 1\,\text{pc}$, the dominant heating source is the sun. The dust mass budget is fairly small ($M \lesssim 10^{26}$g). However, the typical dust temperature is too hot to account for the MSAM sources. The dust temperature is

$$T_d = [\frac{L_\odot}{4\pi D^2} \cdot \frac{c^2}{2\pi h} \cdot \frac{1}{\epsilon\zeta_{4+\alpha}}(\frac{c}{2\pi a})^\alpha]^{\frac{1}{4+\alpha}}, \tag{19}$$

where $\epsilon \sim 0.1$ for dielectric dust grains, $\alpha \approx 1.5$ is the gain emissivity index and a is the grain radius. For typical dust grains of radius $r_d = 0.5\mu$m, the grain temperature is $T_d = 50K$ for $D = 0.1$ pc.

In the far solar neighborhood, $D \sim 100$ pc. One expects the heat source to be diffuse star light. Dust can be very cold if the radius of the particles is large (Rowan-Robinson 1991) or if they are fractals or needles (Wright 1993). Let us first consider fractals and needles. The physics of far infrared emission from fractals or needles differs from those of the spherical dust we considered in the previous section. Since fractals and needles have cooling times which are shorter than the average arrival times between incoming photons, the emission from fractals and needles are not determined by their equilibrium temperature but rather by their enthalpy $U(T)$, mass spectrum and absorption efficiency (Wright 1993).

The problem with explaining point sources with emission from fractal dust or needles is that the spectra of the IR emission differs from the CBR spectrum considerably due to the transient heating by single photon absorption events. The heat capacity of the dust is very small at low temperatures ($T < 10K$), and absorption of a single optical photon will increase the temperature to a very high degree unless the fractal or needle building block is large enough. The average energy of a photon in the radiation field given by Eq. (2) is

$$\bar{E} = 3kT_s \frac{\zeta(4)}{\zeta(3)} = 2.3\text{ev} \tag{20}$$

for $T_s = 10^4 K$. The enthalpy is

$$U_g(T) = \frac{4.15 \times 10^{-22} T^{3.3}}{(1 + 6.51 \times 10^{-3} T + 1.5 \times 10^{-6} T^2 + 8.3 \times 10^{-7} T^{2.3})} \text{ergs/atom} \tag{21}$$

for graphite (Guhathakutra & Draine 1989). The temperature increase of a building block consisting of N atoms when absorbing one photon of energy $\bar{E}$ is

$$\bar{T} \approx \frac{10^3 K}{N^{0.3}}. \tag{22}$$

Thus, $N > 10^{10}$ to avoid excessive spectral deviation from CBR, or, the radius of building block must be greater than $r_b \sim 0.1\mu$m, which is about the size of typical dust grains that absorb in the optical band. For fractals of dimension D, the emissivity is enhanced by $(L/r_b)^{3-D}$, where L is the size of the fractal grain. To reach an equilibrium temperature of several Kelvin, L must be much greater than r_b. Thus, even for fractal grains the size is large.

For clouds of large radius ($r_d \approx 30\mu m$) grains to produce MSAM-like sources, the dust mass is

$$M_d \sim 1 M_\odot (\frac{D}{100\,\text{pc}})^2. \tag{23}$$

Taking a typical gas-to-dust ratio $\eta = 160$, the mass of the gas cloud is $M = 40M_\odot$ for $D \approx 50pc$. The angular size of the clouds located at D = 50 pc is $10'$ for $l = 0.15\,\mathrm{pc}$. Although it is very unlikely that dust can be cooled down to a few Kelvin in the solar neighbourd, this window remains open for explaining the MSAM sources.

3.3.2 Clouds in the ISM

In this case, the clouds are concentrated in the galactic plane. There will be no high galactic latitude dust emission from these dust clouds and hence there will be no effects on the MSAM experiment, which samples high galactic latitudes, even if they exist in the ISM.

3.3.3 Dust in Cold Halo Gas Clouds

It has been suggested that cold molecular gas clouds might be the dominant form of galactic dark matter, distributed either in a large disk (Pfenniger, Combes and Martinet 1994) or flattened halo (Gerhard & Silk 1994). The latter model leads to the natural possibility of cold dust clouds far from the galactic plane. The dust temperature at the periphery of the galaxy will be as cool as a few Kelvin even if the conventional, physically acceptable dust emissivity is adopted. One initial worry is that dust emission from such clouds at high galactic lattitude would have dramatic effects on the experiments that are searching for microwave background fluctuations at millimeter and submillimeter wavelength. We will show here that for the cloud models given by Gerhard & Silk (1994), there is virtually no effect on the CBR from dust emission. In the model where the clouds are in near-hydrostatic equilibrium, for a cloud of density $10^4 cm^{-3}$ and temperature 100 K to satisfy the Jeans criterion requires the size and mass of the cloud to be $L = \lambda_J/2 = 0.64pc$ and $M = 85N_{23}^{-1}M_\odot$. Here N_{23} is the hydrogen column density in units of $10^{23}cm^{-2}$. Demanding the cloud-cloud collision time scale to be at least a Hubble time constrains the column density to be $N_H > 8 \times 10^{23}\,\mathrm{cm}^2$. Thus, the mass of the clouds is limited to be $M \lesssim 10M_\odot$. Even if dust dominates in these clouds, the flux at $5.6\mathrm{cm}^{-1}$ will be $S_\nu \sim 1\mathrm{mJy}$. The angular size of the dust region is $\theta_d \sim 10''$. After smoothing over the beam, the observed flux will be around $1\mu\mathrm{Jy}$, several orders of magnitude smaller than the flux from CBR temperature fluctuations.

3.3.4 Primeval Dust

The last possibility of high latitude dust emission that we consider arises from primeval galaxies at high redshift (Bond et al 1986). The angular size of the dust envelope around a primeval galaxy at redshift z is given by:

$$\theta = \frac{l(1+z)}{D_H}, \quad D_H = 2H_0^{-1}(1 - \frac{1}{\sqrt{1+z}}). \tag{24}$$

Here, l is the linear size of the primeval galaxy, which is around 100 kpc. The typical angular size of the possible point sources produced by a primeval galaxy is:

$$\theta = 1.14h(\frac{l}{50kpc})(\frac{z}{5})\text{arcminute} \tag{25}$$

The temperature of the CBR scales linearly with redshift z, $T_c = 2.73(1+z)K$. At the periphery of the primeval galaxy with D=50 kpc, the dust temperature is $T_d = 24(\frac{z}{5})K$ for grain size $r_d = 0.5\mu$m, which is hot in the usual sense. The observed flux density will be:

$$S_{obs} = 3.45\text{Jy}(M/7.85\times 10^3 M_\odot)(\frac{2\theta}{\theta_{FWHM}})^2(50kpc/D_H)^2(1+z)^{2+\alpha} \tag{26}$$

To explain the MSAM experiment in the framework of primeval dust, the dust mass should be:

$$M_d \sim 10^{12} M_\odot. \tag{27}$$

This is about three orders of magnitude larger than the typical dust mass in observed IR galaxies. The bolometric luminosity of the MSAM sources if they are located at cosmological distances is $L \sim 10^{16} L_\odot$, much brighter than the brightest-known IRAS galaxy F10214+4724. It is improbable that the MSAM sources are primeval galaxies.

In conclusion, we have examined the nature of the putative MSAM sources and shown that foreground radio sources or and the SZ effect in foreground rich clusters are ruled out as dominant contributions. Unless the dust emissivity is unphysically small, cold dust emission can also be ruled out.

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REFERENCES

Bartlett, J.G., Blanchard, A., Silk, J. & Turner, M.S. 1994, Fermilab-Pub-94/173-A

Bennett, C., et al., 1992, ApJ, 396, L7

Bennett, D, & Rhie, S., 1991, Phys. Rev. Lett. 65, 1709

Bond, J.R., Carr, B.J., & Hogan, C.J. 1986, ApJ, 306, 428

Cheng, E.S., et al. 1994, ApJ, 422, L37

Coulson, D., Ferreira, P., Graham, P. and Turok, N. 1994, Nature, 369, 27.

Hinshaw, G., et al. 1994, COBE-Preprint-94-12

Kwan, J. & Xie, S. 1992, ApJ, 398, 105

Gerhard, O.E. & Silk, J. 1994, Preprint

Greenberg, J.M., 1968, in Nebulae and Interstellar Matter, ed. B.M. Middlehurst and L. H. Aller (Chicago, The University of Chicago Press, 1968)

Luo, X.C. 1994, Phys. Rev. D 49, 3810

Peacock, J.A. & Dodds, S.J. 1994, MNRAS, 267, 1020

Peebles, P.J.E. 1994, Preprint, ApJL submitted

Pfenniger, D., Combes, F. & Martinet, L. 1994 A&A, 285, 79

Rowan-Robinson, M. 1992, MNRAS, 258, 787

Smoot, G., et al. 1992, ApJ, 396, L1

Sunyaev, R.A. & Zeldovich, Ya, B., 1980, Ann. Rev. Astr. Astrophys. 19, 537

Turok, N, & Spergel, D.N., 1991, Phys. Rev. Lett., 66, 3093

White, M., Scott, D. & Silk, J. 1993, Ann. Rev. Astro. Astrophys. (in press)

Wright, E., et al. 1992, ApJ, 396, L13

FIGURE CAPTION

Fig. 1: The spectral density of various sources at submillimeter range. The solid line is the CBR anisotropies; The dotted line is SZ flux from a rich cluster; The short dashed line is for radio sources (spectra index -1); The long dashed lines are for 4K cold dust emissions with different dust emissivity $\alpha = 1.5, 1.0, 0.5, 0.0$, from the top to the bottom.

Fig.2a: Best fit spectral slope for SZ effect.

Fig. 2b: Best fit spectral slope for radio sources.

Fig.2c: Best fit spectral slope for 4K dust emission with dust emissivity $\alpha = 1.5$.

Fig.2d: $\alpha = 1.0$.

Fig.2e: $\alpha = 0.5$.

Fig.2f: $\alpha = 0.0$.